An Evaluation of Video Intelligibility for Novice American Sign Language Learners on a Mobile Device

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ABSTRACT

Language immersion from birth is crucial to a child's language development. However, language immersion can be particularly challenging for hearing parents of deaf children to provide as they may have to overcome many difficulties while learning sign language. We intend to create a mobile device-based system to help hearing parents learn sign language. The first step is to understand what level of detail (i.e., resolution) is necessary for novice signers to learn from video of signs. In this paper we present the results of a study designed to evaluate the ability of novices learning sign language to ascertain the details of a particular sign based on video presented on a mobile device. Four conditions were presented. Three conditions involve manipulation of video resolution (low, medium, and high). The fourth condition employs insets showing the sign handshapes along with the high resolution video. Subjects were tested on their ability to emulate the given sign over 80 signs commonly used between parents and their young children. Although participants noticed a reduction in quality in the low resolution condition, there was no significant effect of condition on ability to generate the sign. Sign difficulty had a significant correlation with ability to correctly reproduce the sign. Although the inset handshape condition did not improve the participants' ability to emulate the signs correctly, participant feedback provided insight into situations where insets would be more useful, as well as further suggestions to improve video intelligibility. Participants were able to reproduce even the most complex signs tested with relatively high accuracy.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Evaluation*; K.3.1 [**Computers and Education**]: Computer Uses in Education—*Computer-assisted instruction*

General Terms

Languages, Human factors, Experimentation

Keywords

American Sign Language, mobile devices, computer assisted language learning

1. INTRODUCTION

Approximately 77 percent of deaf children are born to two hearing parents [6]. In many situations, the birth of a deaf child is the first experience these parents have with American Sign Language (ASL) and the Deaf community. They are faced with the difficult process of learning sign language both to provide their children with linguistic models and to be able to communicate with their children more effectively. Classes are available for parents to learn ASL, but the parents might have to drive long distances to reach the class. Time away from home can be difficult to arrange for parents with young children to care for.

Children who experience a delay in acquiring their first language are less able to fully learn all of the nuances of their first language and will also have more difficulty learning other languages throughout their life [15]. Parental involvement in particular, plays a significant role in how well a deaf child born to hearing parents is able to learn the language [16]. Parental language models do not need to be perfect. Even when provided with imperfect signing models by parents, a deaf child is capable of learning sign language to a level consistent with that of native signers [19].

We have been developing a system to help hearing parents learn sign language on their mobile devices [10]. This work has shown that learning ASL on a mobile device can improve a novice signer's vocabulary better than when learning on a desktop computer. One area where more investigation is needed is in helping novices to generate the signs they are learning as opposed to merely recognizing a sign from a video. In this paper we describe the first step in our attempt to improve parents' ability to generate sign language.

The goal of the study described in this paper is to determine the appropriate video resolution needed to present new signs to novice sign language learners. A secondary goal is to determine the benefits, if any, of including more detailed information about handshapes in the signed videos.

2. RELATED WORK

Although many groups are working on developing virtual signing avatars to help the Deaf community for a variety of sign languages [4, 9, 8], few projects include evaluations of sign intelligibility. Glauert et al. investigated the intelligibility of signs from virtual avatars in the VANESSA system. However, only about 60% of the avatar's phrases were recognized successfully by the Deaf participants [7]. Improvements for signing avatar systems are being developed which can improve sign comprehension [12]. These projects have been focused on fluent signers, not the novice signers who are the targets of our research.

There are a few instances of employing either signing avatars or video for educating novice signers. Karpouzis et al. incorporated animations of virtual characters performing Greek Sign Language into an educational system for Greek elementary school students [14]. No evaluation was performed to compare comprehension of signs from virtual avatars against comprehension of signs from other sources. Sagawa and Take-uchi investigated a teaching system for helping novice signers learn Japanese Sign Language [18]. This system used avatars in two ways: as an exemplar of what the person should sign and as a reflection tool showing learners what they actually signed. Participants viewed the avatars performing the exemplar and their own sign simultaneously to help with self evaluation. Around half of the participants responded positively to the intelligibility of animations. This paper did not report measures of the participants' actual sign performance. Johnson and Caird [13] investigated the effect of frame rate and video presentation (normal versus point light video) on novices ability to match signs with their English equivalent. There was no effect of frame rate, but there was an effect of video presentation. This study focused on impact of video quality on the recognition of signs and not on the production of signs which is the focus of our study.

Research investigating video intelligibility of ASL on mobile devices focuses on video quality for ASL experts [3, 2]. Ciaramello and Hemami created a metric for predicting the intelligibility of compressed video based on fluent signers' gaze patterns when observing signs [3]. Cavender et al. investigated video intelligibility in the context of a system for members of the Deaf community to communicate via video chat on a mobile phone [2]. Conversations needed to occur in real-time, therefore the focus was on finding the appropriate encoding settings for capturing signed video on a mobile device and transmitting it over a network with limited bandwidth. In our system, videos can be stored directly on the mobile device. Thus, we have more freedom to deploy videos at higher frame rates and of a larger size. Cavender et al. and Ciaramello and Hemami could take advantage of knowledge about how fluent Deaf signers perceive signs [17]. It was necessary in our study to ensure that videos provided sufficient detail for novice signers to learn nuanced facial expressions and complex handshapes from them to reproduce the signs and not just recognize them.

3. EVALUATING VIDEO INTELLIGIBILITY

In this section we describe the vocabulary selected for the study, how videos were generated, as well as the method used to determine an appropriate resolution for presenting sign language videos to novices on a mobile device.

3.1 Vocabulary selection

We selected a vocabulary of 80 signs for this study. These signs are a subset of the MacArthur-Bates Communicative Development Inventory (MCDI) [5]. The inventory is used by parents to track the linguistic development of their children and was originally developed for English. The signs tracked in the inventory are commonly used by parents and children between birth and 35 months. The MacArthur-Bates inventory has been validated in many languages besides English including American Sign Language [1]. Table 1 lists the 80 signs separated by category. When choosing which signs to include in the study, emphasis was placed on signs that could be used by very young children but could still allow more complex phrases to be created from them as the children develop. The vocabulary choices were verified by a sign language linguist.

Figure 1: The Motorola DROID as used to display signed video in the experiment

3.2 Video creation and presentation

We created four video presentation conditions to be displayed on a Motorola DROID mobile phone running the Android 2.1 operating system (Figure 1). The native resolution of the Motorola DROID is 854x480. The signer in the videos is a hearing individual with 20 years of ASL experience. All videos used in the study were recorded with the same location, lighting conditions, background, and clothing and were encoded using the H.264 codec. The average duration of the videos was 3.18s ($SD = 0.45s$) and the video frame rate was 25 fps. The four conditions can be seen in Figure 2. Three of the conditions involved the manipulation of video resolution resulting in high, medium and low resolution conditions. In the highest resolution condition, a 640x480 pixel video was shown. The high resolution video can be seen in Figure 2a. 640x480 is the highest resolution the mobile device is capable of displaying. The resolution was halved for the medium condition resulting in a 320x240 pixel video, shown in Figure 2b. The low resolution condition halved the resolution again, resulting in a 160x120 pixel video, seen in Figure 2c. The average file size of a high resolution video was approximately 340 KB. The average file size of a low resolution video was approximately 129 KB. In all three of the resolution manipulation conditions, the video was stretched so that in every resolution, the videos appeared to fill the same physical screen size as the high resolution video, 60 mm wide by 45 mm high. The final experimental condition involved adding zoomed-in views of the sign handshapes to the high resolution video. This inset condition can be seen in Figure 2d.

Table 1: Vocabulary by category

Adjectives			
BAD	BIG	CAREFUL	COLD
GOOD	HAPPY	HOT	HUNGRY
LITTLE	SICK	THIRSTY	TIRED
Animals			
CAT	DOG		
Clothing			
JACKET	PANTS	SHOES	
Food			
APPLE	BANANA	FOOD	JUICE
MILK	SWEET		
House			
BATHROOM	BEDROOM	HOME	
Locations			
SCHOOL			
Nouns			
BOOK	MEDICINE	SOAP	TOY
WATER			
People			
BABY	BROTHER	DAD	GRANDPA
GRANDMA	MOM	PERSON	SISTER
Prepositions			
DOWN	IN	OFF	ON
OUT	UP		
Pronouns			
I	MY	THAT	THERE
THIS	YOU	YOUR	
Question Signs			
WHAT	WHERE	WHO	
Routines			
HELLO	MORE	NO	NOT
PLEASE	THANK-YOU	YES	
Times			
NOW	TOMORROW	YESTERDAY	
Transportation			
CAR	TRUCK		
Verbs			
DRINK	EAT	FINISH	GO
HELP	HURRY	LOOK	LOVE
SLEEP	STOP	WAIT	WANT

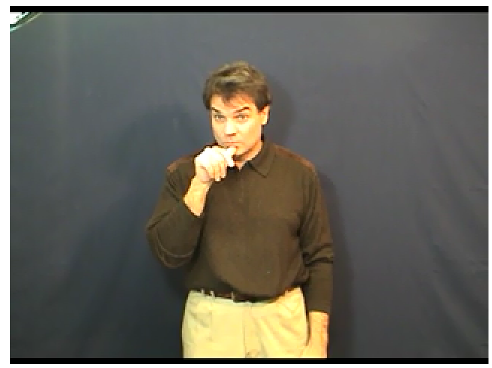
3.3 Experimental Method

In order to ensure equal presentation of each condition over all of the participants in the study, the 80 signs were separated into four groups. Each group of signs was associated with a different condition for participants based on a partially balanced Latin square. The order of presentation for all 80 signs was then randomized so that each participant saw the words in a unique order to avoid ordering effects.

The experimental procedure can be seen in Figure 3. Participants watched the video for a sign in one of the four conditions (3a). After the video finished playing, participants were prompted to recreate the sign (3b). To ensure that the participant performed the sign, the button to advance to the next screen was hidden for 2 seconds. After pressing the button, participants were first asked to rate the quality of the video in terms of resolution on a seven-point Likert scale (3c). Participants had to make a selection for the next button to appear. Finally, participants were asked to rate their difficulty in determining the details of the sign from the video (3d), again on a seven-point Likert scale. This process of viewing, signing, and rating was repeated for all 80 signs in the study.

The experimental procedure was explained to the participants first with screen captures of the interface. They were then allowed to use the study application as practice with four videos of signs not part of the main study. All videos during the demo session were displayed using the highest video resolution. Before starting the main study, partici-

(a) High resolution



(b) Medium resolution

(c) Low resolution

(d) High resolution + inset

Figure 2: Four video conditions for the sign WHO

(a) Watch video (b) Sign what was just seen

(c) Rate video quality (d) Rate video intelligibility

Figure 3: Screen progression on the mobile device

pants were instructed that there were a minimum of two conditions and shown pictures of a high resolution still image and an still image from the inset condition so that they were not confused by the extra components upon initial presentation. Once participants were comfortable with the experimental procedure, data collection began. Participants were invited to place the phone on a small table approximately waist-high while they were signing. Many participants chose to hold the phone when performing one-handed signs and only used the table for two-handed signs.

4. RESULTS

Twenty participants were recruited for the study. Participants were between the ages of 20 and 40 with a mean age of 26.55 ($SD = 4.74$). Fifteen participants were male and five were female. Participants were also asked about their hand dominance because the performance of some signs is dependant on the dominant hand. Fifteen participants reported being right-handed, four were left-handed, and one was ambidextrous. Because the focus of the study was on people's ability to interpret video presented on a small mobile device, participants were also asked to report how often they viewed video on a mobile device such as a phone or media player. Seven participants never watched video on a mobile device and eight did so less than once a week. Three participants reported watching video on a mobile device once a week. Only two participants reported watching video daily on a mobile device. All participants had no previous signing experience other than some knowledge of finger spelling.

Data collected included time to generate the sign, quality and intelligibility of the videos, and the participant's sign generation scores. Time to generate the sign was considered to be the time from when the video stops playing to when the participant pushes the next button on the interface after signing. Video quality and intelligibility were determined by the participants' responses to the two seven-point Likert scale questions for each of the 80 signs. The sign generation scores were determined by a sign language linguist who reviewed video footage of the participants' signs. Participants would receive two points each for handshape, motion, and location on the body and one point for having the correct orientation. There was no partial credit for a component if partly correct. Either the participant received the full points for a component or they received a zero for that component. Even though in some cases a fluent signer might be able to understand the meaning from signs which are slightly inaccurate, we decided to use a strict rating structure to understand the kinds of errors which were more likely based on video presentation. After completing the study, participants were asked for reactions to the study including any issues with video presentation and sign generation. This information will also be reported.

4.1 Perception of video quality and intelligibility analysis

In this section we will describe the results from the participants' Likert scale responses for each video's quality and intelligibility. Although the statement regarding intelligibility was worded negatively in the study interface, for the purposes of analysis we flipped the responses so that all positive results, highest quality and highest intelligibility result in a higher rating on the Likert scale.

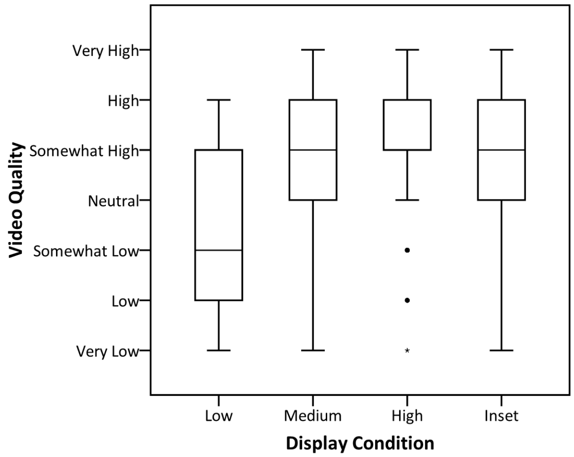
The results of the Friedman Test indicated that there was a statistically significant difference in video quality ratings across the four conditions (low, medium, high, inset), $\chi^2(3, n = 20) = 26.16$, $p = 0.00$. A post hoc Wilcoxon Signed Rank Test revealed that the low resolution video condition ($Md = 3.5$) was of significantly lower quality than the medium resolution condition ($Md = 5.0$), $z = -3.08$, $p = 0.002$, with a medium effect size ($r = 0.49$), the high resolution condition ($Md = 5.75$), $z = -3.20$, $p = 0.001$, with a large effect size ($r = 0.51$), and the inset condition ($Md = 5.0$), $z = -3.14$, $p = 0.002$, with a large effect size ($r = 0.50$). There were no significant differences found between the medium, large, and inset video conditions with respect to perception of video quality. This result indicates that our participants were able to notice a significant decrease in video quality in the low condition, but could not distinguish between medium and high resolution videos. Figure 4a shows box plots of the quality ratings by display condition.

With regards to video intelligibility, the results of the Friedman Test indicated that there was no statistically significant difference across the four conditions: low ($Md = 5.0$, medium ($Md = 6.0$), high ($Md = 6.0$), and inset ($Md = 5.5$), $\chi^2(3, n = 20) = 4.37$, $p = 0.22$. Figure 4b shows box plots of the intelligibility ratings by display condition.

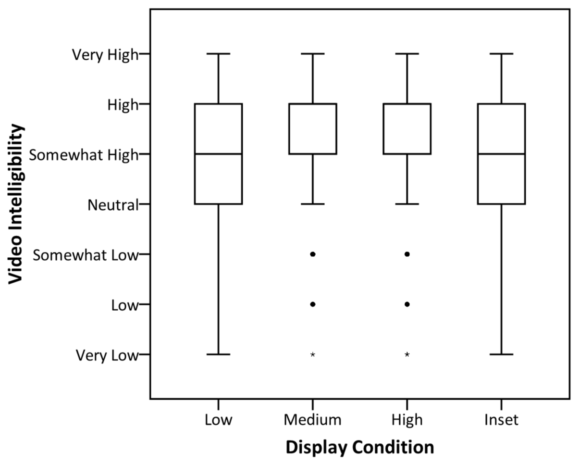
4.2 Sign generation times

We logged timing information for all signs to calculate the amount of time required for the participants to generate the signs. This time data was calculated by subtracting the time stamp corresponding to when the video stopped playing from the time stamp corresponding to when the participant pressed the "next" button after sign completion.

A one-way repeated measures ANOVA was conducted to compare sign generation time under four conditions: low, medium, and high resolution as well as the inset video condition. There was not a significant effect for condition, $F(3, 17) = 1.60$, $p = 0.22$. The time to sign did not change based on the video's condition of presentation. The average sign generation times by condition are presented in Figure 5. The error bars represent one standard deviation from the mean.



(a) Quality ratings



(b) Intelligibility ratings

Figure 4: Boxplots from user ratings

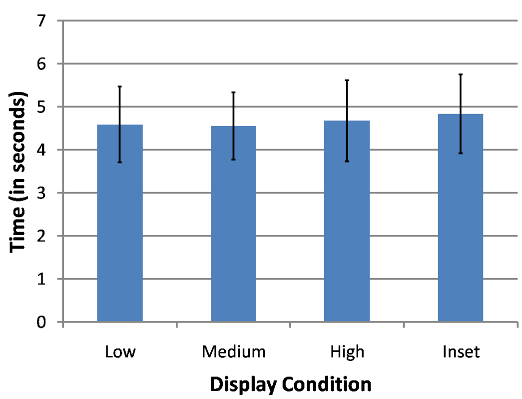


Figure 5: Average sign generation time by condition

4.3 Analysis of sign generation

The results of a one-way repeated measures ANOVA indicated that there was no statistically significant difference in sign generation scores across the four conditions: low, medium, high, inset, $F(3, 17) = 2.40$, $p = 0.08$. These results are summarized in Figure 6. The error bars represent

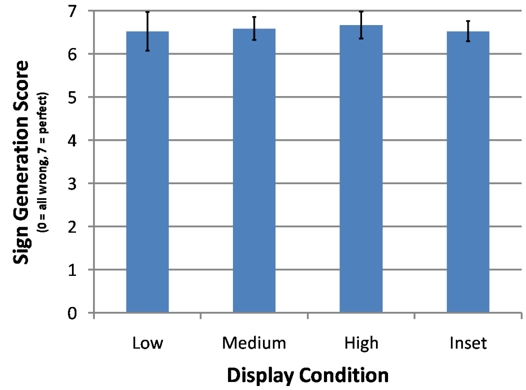


Figure 6: Average sign generation scores by condition

Table 2: Means and Standard Deviations of Sign Production Components by Condition

Condition	Handshape M(SD)	Motion M(SD)	Location M(SD)	Orientation M(SD)
Low	1.78(0.17)	1.86(0.19)	1.92(0.14)	0.96(0.05)
Medium	1.80(0.17)	1.88(0.13)	1.93(0.09)	0.98(0.03)
High	1.87(0.13)	1.89(0.16)	1.94(0.09)	0.98(0.04)
Inset	1.78(0.14)	1.85(0.14)	1.93(0.08)	0.97(0.06)

one standard deviation from the mean. When one-way repeated measures ANOVAs were calculated for all of the subparts of the sign generation scores there were also no statistically significant differences for handshape ($F(3, 17) = 1.98$, $p = 0.13$), motion ($F(3, 17) = 0.81$, $p = 0.49$), location ($F(3, 17) = 0.26$, $p = 0.86$), or orientation ($F(3, 17) = 1.00$, $p = 0.40$). The means and standard deviations of the handshape, motion, location, and orientation component subscores for sign generation are summarized in Table 2.

The relationship between sign difficulty (as measured in a study by Henderson-Summet et al. [11]) and sign generation scores (as rated by the sign linguist in this study) was investigated using the Spearman rho correlation coefficient. There was a small, positive correlation between the two variables, $r = 0.22$, $n = 80$, $p = 0.049$, with easier signs associated with higher sign generation scores (see Figure 7).

We intentionally gave the participants no instruction on which hand should be performing which aspect of the sign and did not adjust video presentation by handedness to see how participants would interpret the video. Figure 8 shows a box plot of the percentage of the time that participants used the right hand as dominant based on their handedness: right, left, and ambidextrous. An independent-samples t-test was conducted to compare the percentage of times the right hand was dominant for right-handed and left-handed participants. There was no significant difference in scores for right-handed individuals ($M = 84.3$, $SD = 34.3$) and left-handed individuals ($M = 71.3$, $SD = 32.9$); $t(17) = 0.68$, $p = 0.50$ (two-tailed).

4.4 Participant responses

After completing the study, participants were asked for feedback on their experience. This information will be valuable in determining how our future sign language learners will be able to interact with the sign videos.

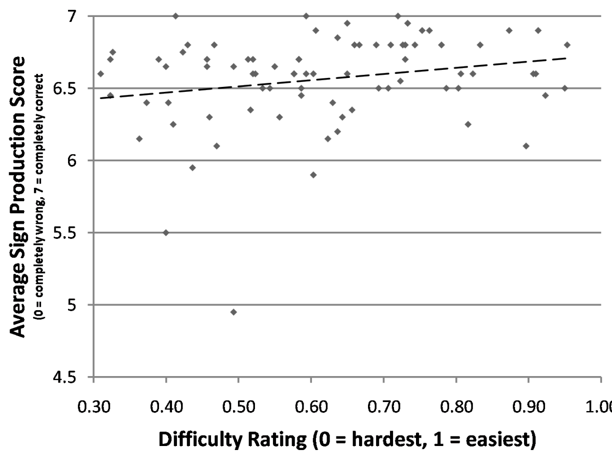


Figure 7: Relationship between sign difficulty and sign generation scores

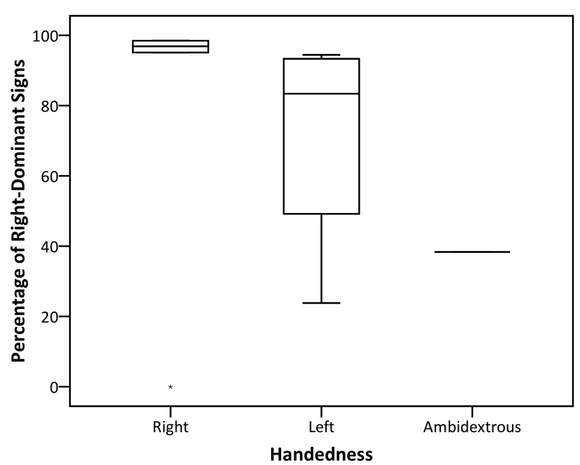


Figure 8: Percentage of signs participants used their right hand as dominant based on handedness

The inset condition received the most negative feedback. Eight out of the twenty participants reacted negatively to the inset condition. Participants remarked about the difficulty of attending both the handshapes presented in the insets and to the motion of the video at the same time. One participant said "If you look at the inset first, then look at the motion, you don't know what the action was." This result is one disadvantage of a study design with only a single presentation of a sign. Another participant reported that there was a trade-off in the inset condition. In really complex signs, there was too much occurring, both from changing handshape insets and in the motions from different parts of the body. In really simple signs, the insets were unnecessary. Even so, for some medium difficulty signs, the insets were sometimes helpful as reported by two of the participants. Three participants reported wishing that they could repeat the video on the longer, more difficult signs. This ability may make the inset condition more desirable and less of a distraction since the learner could focus on different aspects of the sign on different viewings. Five participants also suggested reducing the speed of the video. The ability to change sign speed would be very helpful for more complex signs, although to make sure that novices become accustomed to seeing a sign at a normal pace, it should still be possible to view the sign at full speed as well.

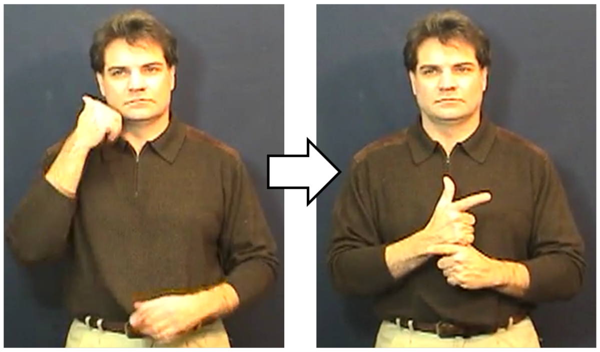
Seven of the twenty participants reported that the resolution or quality of the video was not what determined their success at reproducing the sign. Six participants reported that they felt the difficulty of reproducing a sign was determined much more by the complexity of the sign.

Another area for investigation suggested by some of the participant comments relates to hand dominance. We intentionally did not manipulate the video (i.e. flip the video) based on a participant's reported hand dominance in order to determine how views respond to the video with no knowledge of sign. Three participants made remarks about how to interpret handedness in the video. One participant didn't directly ask about handedness but remarked that the hardest part of signing was determining which hand should be performing what action. This issue may be solved partially by providing a lesson on hand dominance and partially by reducing the playback speed of the video. The other two participants did directly comment about hand dominance. One participant reported mapping their own right hand to the signer's right hand. Another participant asked at the beginning whether they should mirror the signs or flip them. When told to do whatever was easiest, the participant decided that it was easier to mirror the video.

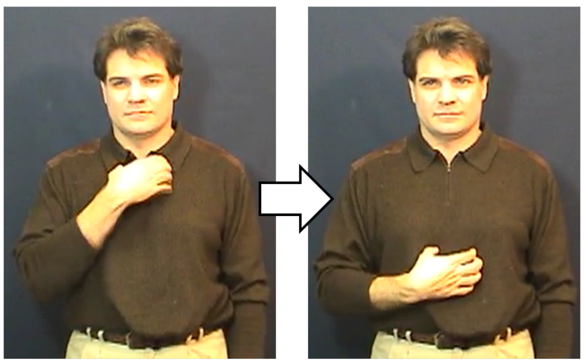
5. DISCUSSION

Although participants noticed a significant difference in sign quality between the low resolution display condition and the other three display conditions, the use of low resolution video did not significantly impact the time required to generate signs, the intelligibility of the videos, or even the quality of the participants' repeated signs. This result is positive because it indicates that the use of smaller, low resolution videos in a sign language teaching system does not adversely affect the intelligibility of the signs. An advantage of using smaller file sizes is that it will be possible to store more signs on the phone's memory card. Also, if new videos need to be downloaded from a server, it will require less time and less bandwidth due to the smaller file size. If an interface has a lower time to access and navigate through, then it will tend to have higher usage [20].

Participants were correct in their observations that the difficulty of the sign was related to how well they were able to reproduce the sign. We did find a significant relationship between the difficulty of a sign and the average sign production score in this study. This result indicates that in future studies we should pay more attention to how participants interact with the system while learning more complex signs such as SISTER (Figure 9a), which was one of the signs most often incorrectly signed in this study. More opportunities to view these difficult signs or more options to view the video at different speeds might help the participants to learn to sign SISTER as well as they were able to sign easier signs such as HUNGRY (Figure 9b). Even the signs that participants reproduced correctly the least often received fairly high scores. Only four signs received average scores lower than 6 points. Those four signs were WHO ($M = 4.95$), WHAT ($M = 5.5$), WATER ($M = 5.9$), and WHERE ($M = 5.95$). The rela-



(a) SISTER



(b) HUNGRY

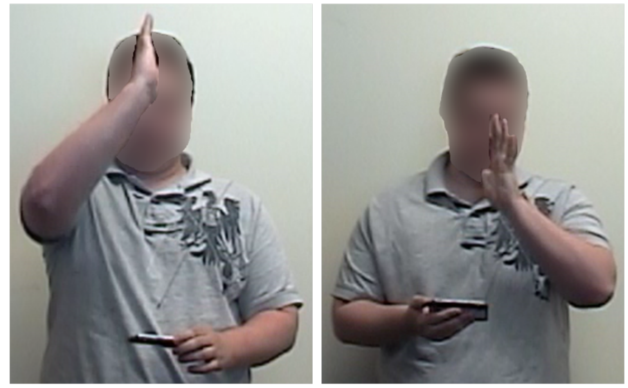
Figure 9: Screenshots from the videos for one of the hardest signs to reproduce, (a), and one of the easiest, (b)

tively high performance across all signs indicates that the mobile device is appropriate for learning how to sign.

Our participants did not show consistent patterns of using a dominant hand in their signs. Figure 10 shows how one participant was inconsistent signing with a single dominant hand even with two very similar signs. There was also no significant difference between right- or left-handed participants using their right hand. Some participants explicitly asked what strategy they should use to interpret the videos, and even they were not consistent in following their strategy. If the one participant's observation was correct, that it was easier to mirror the sign than to match the handedness of the video, then we would have seen a higher prevalence of left-hand dominance. This inconsistency is evidence that early in the usage of a sign language learning system it will be important to both inform the learners about the role of the dominant hand in signing as well as allow the users to choose what presentation strategy they would like to use: mirrored signing, where the learner mirrors what the video shows, or matched signing, where the learner matches the actions of his or her right hand with the actions of the signer's right hand in the video.

6. CONCLUSIONS AND FUTURE WORK

We have presented a study investigating the intelligibility of various video presentation methods for novices learning sign language. The results show that it is not necessarily the quality of the video that influences a person's ability to reproduce the sign and much more the difficulty of the sign itself. While some participants remarked that they preferred the higher quality videos, it did not impact their ability to reproduce the signs. The relatively high sign production scores across all signs indicates that learning to sign correctly on a small device is possible.



(a) GRANDFATHER (b) GRANDMOTHER

Figure 10: Dominant hand inconsistency

The information gained from this study will be incorporated into the SMARTSign project[1]. SMART is an acronym for Support Made Available in Real-Time. There will be three components to this system. One component will allow parents to reference signs and sign phrases by their speaking the word or phrase into the phone. This reference system will allow the parent to immediately access relevant vocabulary to communicate directly with their children. The second component will allow parents to learn new vocabulary during free moments throughout the day in a quiz-based format. Parents will be able to watch videos of signs and then choose the gloss from a list of other glosses. The third component will be focused on practicing sign generation. Parents will be able to watch the video of a sign and then be able to record themselves signing to compare and improve their signing abilities. The first deployment of this system to hearing parents learning ASL will be during the 2010-2011 school year. While support for vocabulary learning is a valuable first step for parents learning ASL to communicate with their Deaf children, it is by no means sufficient for learning the grammar and nuances of ASL. We are currently investigating methods to provide parents with assistance on the more complex aspects of the language.

Based on what we learned in this study, we will incorporate the ability to change the speed of playback for videos. Allowing parents to alter the playback speed will help them to learn the details of the sign better. Perhaps playback at slower speeds and allowing parents to replay a sign video will improve the usefulness embedding handshape insets in the video. Because low resolution videos did not degrade the participant's ability to reproduce the signs, we will also be able to rely on an already large library of sign videos available through the MySignLink website[2] in a low resolution format. The ability to use these lower resolution videos means that we will have a larger library of videos available to the parents upon deployment of the system. Participants

[1]http://cats.gatech.edu/content/smartsign

[2]http://cats.gatech.edu/cats/MySignLink/index.htm

were, however, able to tell the difference in quality between low and high resolution videos. Consistently watching low resolution videos may adversely impact a user's willingness to use the system as a learning tool. The lower resolution videos should not be a permanent replacement for high resolution versions of the videos.

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